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SIXTY-NINTH

ANNUAL REPORT

OF THE

DIRECTOR

OF

THE ASTRONOMICAL OBSERVATORY

OF

HARVARD COLLEGE

FOR THE YEAR ENDING SEPTEMBER 30, 1914

BY

EDWARD C. PICKERING

CAMBRIDGE, MASS.
PUBLISHED BY THE UNIVERSITY
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THE OBSERVATORY

To the President of the University: —

Sir, — As the principal work of the Observatory consists in its publications, and its buildings are liable to destruction by fire, an early publication and distribution of its Annals are of the greatest importance. Especial efforts have accordingly been made to complete some of the larger pieces of work. The results of three of these investigations are now printed, so that they cannot be lost. They are the observations with the 15-inch Equatorial, 1892 to 1912, with the 8-inch Transit Circle, 1888 to 1898, and with the 12-inch Meridian Photometer, 1898 to 1912. A discussion of each of these investigations is in progress.

The improvement in photographic processes, especially by the use of yellow light, has replaced visual work in almost all departments of Astronomy. Accordingly, it does not seem worth while to extend by visual observations the scale of photometric magnitudes to very faint stars. This has already been accomplished so far as the twelfth magnitude by the numerous observations made with the 12-inch Meridian Photometer. The 60-inch Common Reflector was purchased, in order that this extension might be made. The images were not found to be sufficiently good to permit this to be done. Excellent results are obtained, however, with the 16-inch Metcalf Telescope and 24-inch Reflector using photographs with yellow light. This work is being prosecuted on a very large scale, as will be described below. A still larger work, the New Draper Catalogue, which will fill at least eight volumes of the Annals, is progressing rapidly, as described under the Henry Draper Memorial. It will form not only the most extensive, but one of the most important, investigations undertaken here. In general, the results attained this year are the completion of earlier lengthy investigations, the substitution of photographic for visual methods, and the undertaking of photographic researches of greater extent than hitherto. The expenses of the Observatory have been curtailed so that this year they do not exceed the receipts. Unfortunately, this has necessarily diminished the output in a still greater proportion.

One of the greatest needs of the Observatory has been partially supplied during the past year by the continued liberality of Mr. G. R. Agassiz. He has provided for two additional assistants to aid in the study of the great collection of astronomical photographs. This collection is estimated to contain 230,000 plates.

Henry Draper Memorial

The New Draper Catalogue continues to be the principal work of the Henry Draper Memorial. Miss Cannon has classified 60,386 spectra during the last year, making the total number 160,541. All of the northern sky and rather more than half of the southern sky have been covered. As excellent plates have been obtained at Arequipa of the remaining regions, it is probable that the entire number will somewhat exceed two hundred thousand. In the course of this work, 6 variable stars, 31 stars having composite spectra, of which 7 are known doubles, and 8 other stars having peculiar spectra have been discovered.

Professor King has continued in charge of the photographic work in Cambridge. Measures of the brightness of images of stars out-of-focus have been made on photographs taken with the 8-inch Draper Telescope. The results for 71 stars agree with those already given in H.A. **59** within a few hundredths of a magnitude, and show no appreciable difference for change of instrument. Corrections computed for the variability of Polaris, which do not exceed 0.05 magnitude, were applied to these values. For 29 stars, observed on more than one night, the average deviation of the individual measures was thus reduced from $\pm.09$ to $\pm.08$ magnitude, showing the validity of the correction for Polaris. The out-of-focus plates with the 13-inch Boyden Telescope at Arequipa are now all taken and measured. A preliminary reduction gives values of color-index which agree closely with those found with the 8-inch and 11-inch Draper Telescopes. The various systematic tests of plates and standard lights have been continued. Many photographs for determining the light of the sky have been taken. All the plates used in these investigations have, with a few exceptions, been measured, and are ready for reduction. The large number of plates which are used for photographing stars by yellow light are now bathed here, with the result that their sensitiveness is three times that of commercial plates. The number of photographs taken during the year with the 8-inch Draper Telescope is 305, making 38,885, in all. 6847 stellar photographs have been taken here.

Boyden Department

The Arequipa Station has continued under the charge of Mr. Leon Campbell. The plan for out-of-focus photographs, described in H.A. **59**, has now been completed by 17 photographs taken with the 13-inch Boyden Telescope, making the total number obtained with this instrument 13,042. It is expected that its principal use will now be for photometric and visual observations. Photometric measures have been made of 25 eclipses of Jupiter's satellites. The number of photographs taken with the Bache Telescope is 830, making 45,108, in all. Some excellent spectrum plates have been obtained with this instrument. The total number of photographs taken at the station during the year was 2,038.

Seismological and meteorological observations have been made regularly. By the aid of Professor Bingham, a wireless receiving apparatus has been installed and time signals are now received regularly every night from the San Christobal Station in Lima. On September 17, a bright southern comet was discovered by Mr. Campbell. The observations with the pyrheliometer undertaken at the request of the Smithsonian Institution have been continued, 3,310 readings having been taken on 168 days.

Bruce Photographic Telescope

The number of photographs taken with this instrument is 245, making 11,051, in all. Its principal work has been photographing the Selected Areas of Kapteyn, the Harvard Standard Regions, and a large number of special regions for the determination of photographic magnitudes on an absolute scale.

Blue Hill Meteorological Observatory

Professor A. G. McAdie assumed charge as Director of the Blue Hill Meteorological Observatory on October 1, 1913. In accordance with a wish expressed by the late Professor A. Lawrence Rotch in one of his scientific papers, the series of observations or rather continuous records of temperature, pressure, wind direction and velocity, sunshine, rainfall, humidity, and cloudiness has been maintained without interruption or change of exposure and methods. It is desirable that these records which are in a class by themselves owing to the open scale and the high character of instruments employed, be continued for many years to come. This thoroughly consistent series now extends over a period of twenty-

nine years. The usual check and comparative readings of temperature at the valley, and temperature and humidity at the base stations, have been made. These values are of special importance in connection with frost studies now under way as part of the larger problem of air drainage in the Neponset valley. Upper air studies have been made by means of kite records on international dates whenever wind permitted such flights. No *ballon-sonde* work has been attempted. Meteorology has been unfortunately committed to the use of terms and units which bore no definite relation to absolute values. It was particularly desirable that pressures should be expressed in percentages or permillages of a standard pressure, and that temperatures should be recorded in degrees absolute. As early as 1908, Professor McAdie suggested the need of new units. Since March 1, 1914, the megabar has been used as the equivalent of an absolute atmosphere at the Blue Hill Observatory, which is thus the first institution to use this consistent notation for expressing pressure in units of force. The storm of March 1–2, 1914, was recorded in this new notation. The remarkable feature was the pressure, which was the lowest recorded in the history of this Observatory, a period of twenty-nine years. It was also the lowest for this part of New England, so far as Weather Bureau records go, a period of forty-four years. In the old notation, this would be expressed as 28.47 inches at sea-level or 27.80 inches at the Observatory. In the new system, the value was 941 kilobars.

A new method has been devised for recording moonlight and cloudiness at night. A sheet of photographic paper, not over sensitive, is inserted in a Campbell-Stokes sunshine recorder. Interesting records were obtained, especially on the night of the Lunar eclipse on March 12, 1914.

Miscellaneous

Variable Stars. — The organization for the observation of variable stars, under the efficient supervision of Mr. W. T. Olcott, has made excellent progress and the number of observers and observations during the past year has again increased. Sequences of comparison stars with maps for identifying them can now be furnished for nearly a thousand variables. Magnitudes have been determined here for all of these stars, on a uniform scale. An important addition to the work has been the preparation of blueprints of 230 of these regions. Any astronomer desiring to undertake work of permanent value, even if he has only a small telescope,

can be furnished with means for carrying on an interesting and useful research. The wide special interest in this matter is shown by the fact that 16,302 observations have been received here, from the observers named below: —

Mr. H. C. Bancroft, Jr., West Collingswood, N. J., 3,006; Mr. J. B. Lacchini, Faenza, Italy, 1,883; Dr. E. Gray, Eldridge, Cal., 1,300; Mr. W. T. Olcott, Norwich, Conn., 1,002; Mr. C. B. Lindsley, Berea, Ky., 903; Mr. C. Y. McAteer, Pittsburgh, Pa., 891; Mr. C. Richter, Los Angeles, Cal., 889; Professor D. Todd, Amherst, Mass., 773; Mr. A. B. Burbeck, North Abington, Mass., 692; Rev. T. C. H. Bouton, Hudson, N. H., 529; Mr. H. L. Baldwin, Washington, D. C., 469; Mr. A. P. C. Craig, Corona, Cal., 398; Mr. H. W. Vrooman, Kokomo, Ind., 361; Mr. S. C. Hunter, New Rochelle, N.Y., 339; Mr. F. C. Leonard, Chicago, Ill., 309; Mr. O. Mach, Dayton, Ohio, 297; Mr. N. Bruseth, Los Angeles, Cal., 265; Mr. S. H. Huntington, Kerrville, Texas, 260; Professor A. S. Young, South Hadley, Mass., 235; Mr. H. O. Eaton, Madison, Wis., 220; Miss H. M. Swartz, South Norwalk, Conn., 200; Mr. M. W. Jacobs, Jr., Harrisburg, Pa., 185; Dr. C. E. Furness, Poughkeepsie, N. Y., 165; Mr. M. Yamasaki, San Francisco, Cal., 147; Mr. E. W. Putnam, New York City, N. Y., 129; Mr. L. Barbour, New York City, N. Y., 115; Mr. F. H. Spinney, Hudson, N. H., 88; Mr. D. B. Pickering, East Orange, N. J., 76; Dr. E. Padova, Padova, Italy, 68; Mr. C. S. Mundt, Alameda, Cal., 59; Mr. D. M. Brunswick, Cambridge, Mass., 25; Mr. F. H. Hay, Los Angeles, Cal., 12; Mr. F. E. Hathorn, Des Moines, Iowa, 10; Mr. G. A. Winterbottom, Springfield, Mass., 2.

In addition, 1,105 observations have been made here by Mr. P. G. O'Reilly, 292 by Miss I. E. Woods, and 823 by Mr. L. Campbell in Arequipa, making the total number 17,417. The corresponding numbers for the five preceding years are, 4,740, 5,578, 2,532, 10,117, 16,830. 2,381 observations were received in September, 1914. This is the largest number ever received for a single month.

16-inch Metcalf Telescope. — 2,496 photographs have been taken with this instrument, making the total number 6,507. A satisfactory system of photographic and photovisual magnitudes has now been adopted. Series of twelve plates are exposed under exactly similar conditions, the first, last, and an intermediate one being on the Pole. All are taken from the same box, and are developed together. Each has an exposure of exactly ten minutes. The magnitudes are then reduced to the system of the Standard Polar

Sequence given in H.A. **71**, No. 3. The average magnitude of the faintest stars shown on these plates is 15.7, when blue light is used, and 12.8 with yellow light. With an exposure of 60^m, the corresponding magnitudes are 16.9 and 14.4. Photographs are taken with an objective prism giving spectra whose lengths from $H\beta$ to $H\epsilon$ are 4.6 mm. The magnitude of the faintest stars whose spectra are seen well enough to be classified is on the average 10.6. 107 photographs of the Moon have been obtained in coöperation with the Yale and Princeton Observatories, making the total number of these photographs 497. Excellent progress has been made under the direction of Professor Russell in the discussion of these photographs.

Observatory of the Rev. J. H. Metcalf. — 163 photographs have been taken by Mr. Metcalf and his assistant at Winchester, with the 12-inch Telescope and the same number with the 6-inch Telescope, making the total number with the larger instrument 1,794. Four new asteroids have been discovered and their positions measured so that their orbits have been, or will be, computed. Three new variables have been found. About a hundred known asteroids have been photographed and their approximate positions determined. In coöperation with the Rechen-Institut of Berlin a search for asteroids has been maintained in a zone extending on both sides of the ecliptic.

24-inch Reflector. — Excellent photographs are now obtained with this instrument, and it is in regular use during a large part of every clear evening. 314 photographs have been obtained making 1,131 in all. Series are taken like those with the 16-inch. Exposures of 15^m and 1^m are made on each plate. The faintest stars shown are 16.8, and 14.0 magnitude, with blue and yellow light, respectively. With 60^m exposure, these magnitudes become 17.6 and 15.2. The method of covering the mirror with a thin coating of celluloid dissolved in amyl acetate, has been employed with complete success. The mirror remains for several months without sensible deterioration, and there is no perceptible effect on the definition.

Globular Clusters. — Professor Bailey, in addition to rendering much aid in the executive work of the Observatory, has continued his studies of the variable stars in globular clusters. The light curves of 72 of the 92 variables in Messier 5 are now complete except for the adoption of standard magnitudes for the comparison stars.

Mandeville Station. — The station at Mandeville, Jamaica, has continued under the charge of Professor W. H. Pickering. The principal instruments are the 11-inch Draper Telescope, and a 1-inch Cooke Anastigmat. Seventeen photographs have been taken with the latter instrument, having exposures varying from ten to twenty-one hours. The larger instrument has been used on nearly every clear night for visual work. A new method of measuring the distances of close double stars has been devised, discarding the micrometer, and depending on the scale employed for determining the ellipticity of the disks of Jupiter's four larger satellites. Stars whose distances exceed 0″.2, or even less, can thus be readily measured with the 11-inch Telescope. A comparison of the Harvard measures of six close doubles with measures made at about the same time with the 36-inch refractor of the Lick Observatory showed an average difference of ±0″.025, the maximum being 0″.049. An examination of all the brighter stars whose parallax exceeds 0″.1 and of all stars brighter than magnitude 3.0 is now being made, and is already complete for one quarter of the heavens, between declinations +60° and −25°. Some new and very close doubles have already been detected.

Much time has been devoted to the planet Mars during its recent opposition. Nearly a hundred drawings, 11 of them colored, were secured. Many well defined spots appear to undergo a gradual shifting, rendering an accurate permanent map of the surface impossible. 244 drawings have been made of portions of the Moon. Certain white masses within the crater Einmart appear to change their positions gradually. A close double canal has been found in Aristillus, intimately connected with the variable dark areas which the observer believes are due to vegetation.

Phillips Library. — The Library of the Observatory has been increased by 396 volumes and 1,747 pamphlets. As 1,582 of the latter have been bound in volumes, the present extent of the library is 14,494 volumes and 35,590 pamphlets. It is scattered through the various rooms of the Observatory, and continues in constant danger of destruction by fire.

Telegraphic Announcements. — Until August cable messages were exchanged between the Kiel Centralstelle and the Harvard Observatory, and 32 announcements of astronomical discoveries, observations, and orbits have thus been interchanged and distributed promptly throughout Europe and America. The cutting of the cables and the impossibility of sending messages in cipher to

any part of Europe has interrupted this system. Plans are accordingly being prepared for a provisional interchange, and meanwhile the present system is unchanged so far as North and South America are concerned. It is requested, therefore, that announcements be sent here, as usual, cablegrams addressed "Observatory, Boston," and telegrams "Harvard College Observatory, Cambridge, Mass." They will be given as wide a distribution abroad as practicable.

Thirty-three bulletins have been issued, making the total number 565. They are printed promptly and not only contain all the telegraphic announcements but much additional information sent for that purpose. They are sent without charge to all receiving the telegrams and at a price less than cost to all others desiring them.

Publications. — During the last year Volumes **63**, Part **2**, Sequences of Comparison Stars for 279 Variables; **69**, Part **2**, Observations with the East Equatorial during the years 1903 to 1912; **73**, Part **1**, Blue Hill Meteorological Observatory, 1909; **76**, No. 1, Absorbing Medium in Space; **78**, Part **1**, Variable Stars in Messier 3, have been distributed. **71**, No. **3**, Standard North Polar Sequence; **76**, No. **2**, Color Equation of Various Star Catalogues, and **76**, No. **3**, Spectra having Bright Lines, are at the binder's. 58 pages of **77** are in type. The set of Annals from **1** to **75** is therefore completed and distributed with the exception of the portions following **71**, No. **2**, and **73**, Part **1**. Portions of **76** and **78** have also been distributed. Five Circulars have been issued whose numbers, titles, and dates are as follows: —

180. Spectra of 825 Stars near the North Pole, December 2, 1913.
181. A Correction to the Physical Ephemeris of Mars, January 17, 1914.
182. The Variable Star *081041*, −41° 3911, H. V. 3372, February 23, 1914.
183. Opposition of Eros (433) in 1914, May 10, 1914.
184. Stars having Peculiar Spectra, September 29, 1914.

Various other publications by officers of the Observatory are described in the *Harvard University Gazette*, each month.

EDWARD C. PICKERING, *Director.*